APCOMS 2009

The 2nd Asia-Pacific Conference on Manufacturing System

Reconfigurable Manufacturing System for Facing Turbulent Manufacturing Environment

PROCEEDING BOOK

NOVEMBER 4th-5th, 2009

YOGYAKARTA, INDONESIA

Optimization of the Use of Railway Track Bearing Waste for Lighting Production

Nur Indrianti †
Department of Industrial Engineering,
University of National Development (UPN) "Veteran" Yogyakarta, INDONESIA
Email: n.indrianti@upnyk.ac.id

Oryza Ashra
Department of Industrial Engineering,
University of National Development (UPN) "Veteran" Yogyakarta, INDONESIA
Email: oryza_ashra@yahoo.com

Abstract. *Recycling is one of the better-known strategies for sustainable manufacturing. The aim of the strategy is to focus manufacturers' attention to the finite resources available to mankind. Furniture industry is one of the industries that are currently facing a problem of resource limitation, in particular in the need of wood as raw material. This paper deals with the case of recycling strategy in a lighting manufacturing industry in Indonesia. The manufacturer uses railway track bearing waste as raw material to produce decorated lamps. The problem is to determine which products to be produced subject to the demand of the products and resource constraints. A linear programming was used as an approach to the problem. The result shows that optimal production could be determined by simulating production alternatives of a railway track bearing waste. The optimal production alternative was then decided using a linear programming.*

Keywords: *recycle, railway track bearing, lighting production, linear programming*

1. INTRODUCTION

A well known definition of sustainable development is given in the 'Brundtland Report' of the World Commission on Environment and Development. In this report the Brundtland Commission defined sustainable development as: "sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 2002).

One of the strategies to implement the concept of sustainable development is sustainable manufacturing. It is a strategy to protect the environment from environmental pollution and degradation by conserving the earth's limited resources and effectively planning for the optimal use of resources and safe disposal waste (Allwood, 2005). The strategies for sustainable manufacturing include inverse manufacturing, recycling, re-manufacturing, reverse logistic, eco-labelling, life cycle assessment, and design for environment (Madu, 2000).

Recycling, re-manufacturing, and re-use have been much interesting as natural resources is going to be depleted. This also happens in wood furniture industry. The industry utilizes virgin wood, which is currently going to be scarce, as primary raw material. Recognizing the need for wood as primary material, furniture industry has become increasingly attractive through substitution initiatives such as using wood waste as a substitute for virgin wood.

PT Lunar Mulia Kreasi is a company located in Sleman, Yogyakarta, Indonesia that produces furniture, lighting, and bags for domestic and overseas markets. Some of the lighting products are made of railway track bearing waste as the primary material. The products include Bima Lamp (BL), Oval Branch Lamp (OL), Neo Pedati Lamp (PL), Megan Lamp (ML), and Natural Erosi Lamp (NL). Considering the demand for the products and resource availability, the problem is which product(s) and how much to be produced in order to get the highest possibly profit. With regard to that problem, the objective of this study is to determine the optimal production of lighting product at PT. Lunar Mulia Kreasi.

2. LIGHTING PRODUCTION

Figure 1 shows the lighting products produced by PT Lunar Mulia Kreasi. Besides railway track bearing waste

† : Corresponding Author

(RTB), PT. Lunar Mulia uses other materials and components such as wood and small branch of hardwood trees, accessories lamps, and electrical components to produce the products. Figure 2 shows the RTB used for producing lighting products at PT Lunar Mulia Kreasi. The size and unit price of RTB waste is $2\text{m} \times 0.22\text{m} \times 0.15\text{m}$ (0.066 m^3) and Rp 125.000,-. The requirement of RTB for producing each product is shown in Table 1.

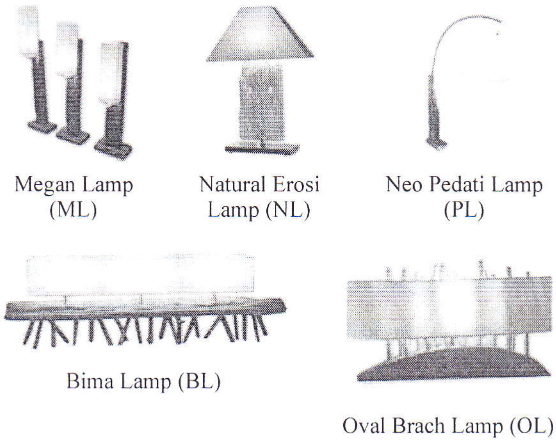

Figure 1: Lighting products produced by PT Lunar Mulia Kreasi

Figure 2: Railway track bearing waste

Table 1: The use of RTB waste for lighting product

Product (P_j)	Name	RTB Use	
		Function	Volume (m^3)
P_1	BL	Base and bottom part	0.066000
P_2	OL	Bottom part	0.011481
P_3	PL	Body part	0.028813
P_4	ML	Body part	0.039600
P_5	NL	Body part	0.002640

Production process of lighting products at PT lunar Mulia Kreasi is shown in Figure 3. While, Table 2 shows the selling price and production cost components of the products.

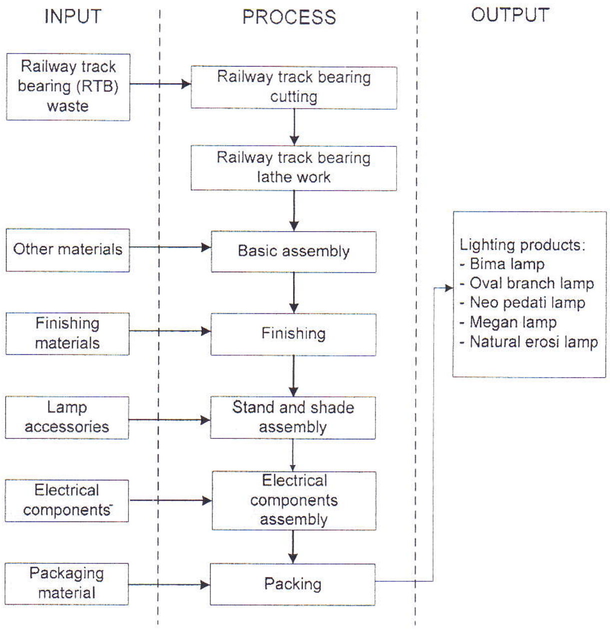

Figure 3: Production process of lighting products

Table 2: Selling price, RTB use, and production cost components

Product (P_j)	RTB use (m^3)	Selling price (Rp/unit)	Material cost (Rp)	Energy use (kWh)	Energy cost* (Rp)	Manhours (hours)	Labor cost (Rp)
P_1	0.066000	1167000	289082	2.025	1134	13.124	73650
P_2	0.011481	500000	132457	0.5819	326	7.680	41625
P_3	0.028813	833500	255724	0.4943	277	10.293	57950
P_4	0.039600	622000	137819	1.207	676	5.60	32300
P_5	0.002640	400000	127040	1.267	710	3.873	22492

*energy price: Rp 560,-/kW

2. MODEL DEVELOPMENT

2.1 Notation

In formulating the problem, we use the following notations:

C_i	:	total production cost of production alternative i
E	:	total energy use (kWh)
M	:	total production capital (Rp)
P_{F_i}	:	profit of production alternative i (Rp)
P_j	:	product j
T	:	total man-hours required (hours)
X_i	:	production alternative i
Cm_{ji}	:	RTB material cost of product j production alternative i (Rp)
y_{ji}	:	number of product j produced by alternative i (unit).
v_j	:	volume of RTB used for producing product j (m^3)
CM	:	unit price of RTB (Rp/unit)
S_{ji}	:	selling price of product j (Rp)
SR_i	:	income resulted from selling the waste of production alternative i (Rp)
Cm_i	:	material cost of production alternative i (Rp)
CL_i	:	labor cost of production alternative i (Rp)
CE_i	:	energy cost of production alternative i (Rp)
CO_i	:	*overhead* cost of production alternative i (Rp)
y_{ji}	:	number of product j produced by production alternative i (unit)

2.2 Production Cost and Profit

The problem is solved by production alternatives approach. Firstly, the railway track bearing waste is simulated using AutoCAD 2006 to find alternative products may be produced. One of the simulations is shown in Figure 4. The result shows that there are three units of Oval Branch Lamp can be produced from one unit of RTB. Simulation results of production alternatives are presented at Table 3.

Figure 4: RTB simulation for production alternative 2

Table 3: Production alternatives of one unit of RTB

No	Alternative (X_i)	Quantity (units)				
		P_1	P_2	P_3	P_4	P_5
1	X_1	1				
2	X_2		3			
3	X_3		1	1		2
4	X_4		1		1	
5	X_5		1			6
6	X_6		2			2
7	X_7			2		
8	X_8			1		4
9	X_9				1	2
10	X_{10}					10

RTB material cost of each product is calculated as follow:

$$Cm_{ji} = \frac{y_{ji}v_j}{\sum_{j=1}^{5} y_{ji}v_j} \times CM \quad (1)$$

Calculation result of material cost of production alternatives is shown in Table 4. Using the data in Table 2, energy and labor cost of production alternatives can be calculated and the result is presented in Table 5. Overhead cost is usually 15% of production cost.

The production process yields wood scrap with selling price of Rp 100.000,-/m^3. The scrap is transported to the buyer using truck with 2% of volume reduction. Based on this data, production waste and its selling price can be calculated and the result is shown in Table 6.

Profit of each production alternative is calculated based on the income resulted from selling the products and waste, production cost, and overhead cost, which can be formulated as follow:

$$PF_i = \sum_{j=1}^{n} y_{ji}S_j + SR_i - \begin{bmatrix} (Cm_i + CL_i + CE_i + CO_i) + \\ 0.15(Cm_i + CL_i + CE_i + CO_i) \end{bmatrix} \quad (2)$$

Using the data and calculation result presented previously, the profit of all production alternatives are calculated using Equation (2) and the result is shown in Table 7.

Table 4: Material cost of production alternatives

Alternative $[X_i]$	Product $[P_j]$	Quantity $[y_{ji}]$	RTB material (Rp) Per product type	RTB material (Rp) Per each product	NonRTB material (Rp) Per each product	NonRTB material (Rp) Per product type	NonRTB material (Rp) Per alternative $[Cm_i]$
X_1	P_1	1	125000	125000	289082	289082	289082
X_2	P_2	3	125000	41667	132457	397371	397371
X_3	P_2	1	31490	31490	132457	132457	642261
	P_3	1	79028	79028	255724	255724	
	P_5	2	14482	7241	127040	254080	
X_4	P_2	1	28095	28095	132457	132457	270276
	P_4	1	96905	96905	137819	137819	
X_5	P_2	1	52528	52528	132457	132457	894697
	P_5	6	72472	12079	127040	762240	
X_6	P_2	2	101631	50815	132457	264914	518994
	P_5	2	23369	11685	127040	254080	
X_7	P_3	2	125000	62500	255724	511448	511448
X_8	P_3	1	91474	91474	255724	255724	763884
	P_5	4	33526	8381	127040	508160	
X_9	P_4	1	110294	110294	137819	137819	391899
	P_5	2	14706	7353	127040	254080	
X_{10}	P_5	10	125000	12500	127040	1270400	1270400

Table 5: Energy and labor costs of production alternatives

Alternative [X_i]	Produk [P_j]	Quantity [y_{ji}]	Energy use (kWh)		Energy cost per alternative (Rp)	Labor cost (Rp)		
			Per each product	Per product type		Per each product	Per product type	Per alternative [CL_i]
X_1	P_1	1	2.025	2.025	1134	73650	73650	73650
X_2	P_2	3	0.582	1.746	978	41625	124875	124875
X_3	P_2	1	0.582	0.582	2022	41625	41625	144559
	P_3	1	0.494	0.494		57950	57950	
	P_5	2	1.267	2.534		22492	44984	
X_4	P_2	1	0.582	0.582	1002	41625	41625	73925
	P_4	1	1.207	1.207		32300	32300	
X_5	P_2	1	0.582	0.582	4584	41625	41625	176577
	P_5	6	1.267	7.603		22492	134952	
X_6	P_2	2	0.582	1.164	2071	41625	83250	128234
	P_5	2	1.267	2.534		22492	44984	
X_7	P_3	2	0.494	0.989	554	57950	115900	115900
X_8	P_3	1	0.494	0.494	3115	57950	57950	147918
	P_5	4	1.267	5.069		22492	89968	
X_9	P_4	1	1.207	1.207	2095	32300	32300	77284
	P_5	2	1.267	2.534		22492	44984	
X_{10}	P_5	10	1.267	12.672	7096	22492	224920	224920

Table 6: Production waste of production alternatives

Alternative [X_i]	Product [P_j]	Quantity [y_{ji}]	RTB use per alternative (m^3)	Scrap volume (m^3)	Volume reduction (m^3)	Scrap volume sold (m^3)	Waste-based income (Rp 100000)
X_1	P_1	1	0.066000	0	0	0	0
X_2	P_2	3	0.034443	0.031557	0.000631	0.030926	3093
X_3	P_2	1	0.045574	0.020426	0.000409	0.020017	2002
	P_3	1					
	P_5	2					
X_4	P_2	1	0.051081	0.014919	0.000298	0.014621	1462
	P_4	1					
X_5	P_2	1	0.027321	0.038679	0.000774	0.037905	3791
	P_5	6					
X_6	P_2	2	0.028242	0.037758	0.000755	0.037003	3700

Table 6: (continued)

Alternative $[X_i]$	Product $[P_j]$	Quantity $[y_{ji}]$	RTB use per alternative (m^3)	Scrap volume (m^3)	Volume reduction (m^3)	Scrap volume sold (m^3)	Waste-based income (Rp 100000)
	P_5	2					
X_7	P_3	2	0.057626	0.008374	0.000167	0.008207	821
X_8	P_3	1	0.039373	0.026627	0.000533	0.026094	2609
	P_5	4					
X_9	P_4	1	0.044880	0.02112	0.000422	0.020698	2070
	P_5	2					
X_{10}	P_5	10	0.026400	0.0396	0.000792	0.038808	3881

Table 7: Profit of production alternatives

Alternative $[X_i]$	Profit [PF_i] (Rp)
X_1	604804
X_2	757636
X_3	1084584
X_4	582729
X_5	1522804
X_6	913257
X_7	801984
X_8	1240205
X_9	738350
X_{10}	2132352

The objective of the production is to maximize profit, and thus the objective function of the problem can be formulated as follow:

Maximize total profit

$$\begin{aligned} Max\ Z &= \sum_{i=1}^{10} P_{F_i} X_i \\ &= 604804X_1 + 757636X_2 + 1084584X_3 + 582729X_4 \\ &\quad + 1522804X_5 + 913357X_6 + 801984X_7 + 1240205X_8 \\ &\quad + 738350X_9 + 2132353X_{10} \end{aligned} \tag{3}$$

The constraints of the problem include the demand of *lighting* products, energy availability, production capacity, and production capital. The company has 1560 kWh energy available in every month. The available man-hour is 1092 hours a month. Monthly financial resource for producing lighting product is limited to Rp. 200,000,000. With regard to the demand, the maximum monthly production of each product type is decided to be 50 units. Production capacity is represented by man-hours availability, which is 156 man-hours per month. Hence, problem constraints can be formulated as follow:

$$P_1 : X_1 \le 50 \tag{4}$$

$$P_2 : 3X_2 + X_3 + X_4 + X_5 + 2X_6 \le 50 \tag{5}$$

$$P_3 : X_3 + 2X_7 + X_8 \le 50 \tag{6}$$

$$P_4 : X_4 + X_9 \le 50 \tag{7}$$

$$P_5 : 2X_3 + 6X_5 + 2X_6 + 4X_8 + 2X_9 + 10X_{10} \le 50 \tag{8}$$

$$\begin{aligned} E &: 2.025X_1 + 1.746X_2 + 3.610X_3 + 1.789X_4 + 8.185X_5 \\ &\quad + 3.698X_6 + 0.989X_7 + 5.563X_8 + 3.741X_9 \\ &\quad + 12.672X_{10} \le 1560 \end{aligned} \tag{9}$$

$$\begin{aligned} T &: 13.124X_1 + 23.040X_2 + 25.718X_3 + 13.280X_4 \\ &\quad + 30.915X_5 + 23.105X_6 + 20.586X_7 + 25.783X_8 \\ &\quad + 13.345X_9 + 38.725X_{10} \le 1092 \end{aligned} \tag{10}$$

$$\begin{aligned} M &: \sum_{i=1}^{10} C_i X_i \le 200000000 \\ &: 562196X_1 + 745457X_2 + 1050918X_3 \\ &\quad + 540733X_4 + 1380986X_5 + 890444X_6 \\ &\quad + 865837X_7 + 1195905X_8 + 685720X_9 \\ &\quad + 1871529X_{10} \le 200000000 \end{aligned} \tag{11}$$

$$X_{1,\dots,10} \ge 0 \tag{12}$$

3. OPTIMAL SOLUTION

The problem is a linear programming and is solved using LINGO *software* with integer value on the production alternatives (X_i). The optimal solution of the problem is shown in Table 8

Table 8: Optimal production

No.	Production alternative (X_i)	Quantity (sets of production)	Products Quantity (units)				
			P_1	P_2	P_3	P_4	P_5
1	X_1	50	50				
2	X_2	0					
3	X_3	0					
4	X_4	6		6		6	
5	X_5	0					
6	X_6	0					
7	X_7	1			2		
8	X_8	0					
9	X_9	25				25	50
10	X_{10}	0					
		Total	50	6	2	31	50

Tabel 8 shows that the optimal production consists of 50 sets of production alternatives 1, 6 sets of production alternatives 4, 1 set of production alternatives 7 and 25 sets of production alternatives 9. In other word, in order to get maximum profit the monthly production of the company should be 50 units of Bima Lamp (P_1), 6 units of Oval Branch Lamp (P_2), 2 units of Neo Pedati Lamp (P_3), 31 units of Megan Lamp (P_4), and 50 units Natural Erosi Lamp (P_5). That production needs 82 units of railway track bearing waste, 206,498 kWh of electrical energy, 1090,091 man-hours, and Rp 49,363,035,- of capital. The optimal production results in 52,997,310,- of profit. Table 9 shows the breakdown of optimal production cost.

Tabel 9: Optimal production cost

Product	Material cost (Rp)	Energi cost (Rp)	Labor cost (Rp)	Total cost (Rp)	Cost per unit (Rp)
P_1	14454100	56700	3682500	18193300	363866
P_2	794742	1955	249750	1046447	174408
P_3	511448	554	115900	627902	313951
P_4	4272388	20954	1001300	5294642	170795
P_5	6352000	35481	1124600	7512081	150242
Total	26384678	115644	6174050	32674372	

Table 9 shows that material cost has the highest contribution to the production cost. In this case Bima Lamp (P_1) is the highest contributor. The table also shows that compared to the other products the production of Bima Lamp (P_1) has the highest unit production cost. Therefore, the company should improve their productivity by increasing the efficiency of energy use and labor-based process in particular for Bima Lamp. Besides improving process productivity, it is important to the company to find alternative materials as substitutes for the materials that are currently used. The secondary materials should be cheap but qualified enough in order to make the products competitive

4. CONCLUSION

We have presented an optimization model of the use of railway track bearing waste for producing lighting products. The model was basically developed based on the case of lighting production at PT Lunar Mulia Kreasi, Yogyakarta Indonesia. The model was to maximize profit with regard to the demand and resource availabilities.

The problem was solved using production alternatives approach and formulated as a linear programming with integer value on the production alternatives. Optimal solution was then determined using LINGO.

PT Lunar Mulia Kreasi can be acknowledged as an environmental conscious manufacturing company. By using railway track bearing waste to produce lighting products the company has considered waste as an alternative resource for producing goods while simultaneously reduces the rate of environmental depletion. However, the utilization of railway track bearing waste for lighting production may generate waste and emission that have environmental impact. Therefore, the optimization of utilizing railway track bearing waste for lighting production could be extended by considering economic and environmental aspects simultaneously.

REFERENCES

Allwood, J. (2005) What is sustainable manufacturing?: Sustainable manufacturing seminar series, 16th February 2005, Institute for Manufacturing University of Cambridge Mill Lane, Cambridge. *http://www.docstoc.com/docs/2319993/ What-is-Sustainable-Manufacturing*. Access date: 24 September 2009 at 20.26.

Keputusan Presiden Republik Indonesia (Kepres) No. 104 Tahun 2003 tentang *Harga Jual Tenaga Listrik Tahun 2004 yang Disediakan oleh Perusahaan Perseroan (PERSERO) PT. Perusahaan Listrik Negara.*

LINDO System Inc. (2006) *Optimization Modelling with LINGO, 6th edition*, LINDO System Inc., Chicago.

Madu, C.N. (2000) *Sustainable manufacturing: strategic issues in green manufacturing. In Madu, C.N., Handbook of Environmentally Conscious Manufacturing,* Kluwer Academic Publishers, Dordrecht, chapter 1, 1-26.

Taha, H.A. (2003) *Operations Research: An Introduction. 7th edition*, Prentice Hall, Englewood Cliff, NJ.

Winston, W. L. (1993) *Operations Research Applications and Algorithms*, Duxbury, Belmont, California.

World Commission on Environment and Development (WCED) (2002) The Johannesburg Declaration on Sustainable Development, World Summit on Sustainable Development (WSSD). *http://www.johannesburgsummit.org/*. Access date: April 2004.

AUTHOR BIOGRAPHIES

Nur Indrianti is a Lecturer in Department of Industrial Engineering, Faculty of Industrial Technology, University of National Development (UPN) "Veteran" Yogyakarta, Indonesia. He received a Doctoral Degree from Department of Industrial Engineering and Management, Graduate School of Decision Science and Technology at Tokyo Institute of Technology, Japan in 2005. Her research interest includes sustainable manufacturing and industrial ecology.

Oryza Ashra is an under graduate student in Department of Industrial Engineering, Faculty of Industrial Technology, University of National Development (UPN) "Veteran" Yogyakarta, Indonesia.